OSSE OBSERVATIONS OF ACTIVE GALACTIC NUCLEI

J. D. Kurfess, W.N. Johnson
Naval Research Laboratory
Washington, DC 20375

and

K. McNaron-Brown
George Mason University
Fairfax, VA 22030

ABSTRACT. The principal results on active galactic nuclei obtained by the Oriented Scintillation Spectrometer Experiment (OSSE) on the *COMPTON Gamma Ray Observatory* are presented. These include observations of 26 Seyfert galaxies in low-energy gamma rays and observations of several of the high-energy gamma ray sources detected by EGRET. OSSE observes a thermal-like spectrum from NGC 4151, and the average gamma ray spectrum of weak Seyferts is significantly softer (consistent with a 45 keV thermal spectrum) than the spectrum below 50 keV. OSSE has not detected any positron annihilation radiation from any Seyfert, and has not detected an MeV excess from these sources. The OSSE observations of several blazars, when combined with the COMPTEL and EGRET data, indicate that the spectral characteristics of these sources vary dramatically, exhibiting power-law spectra with breaks or changes in spectral index in the MeV region which vary from 0 to greater than 1.

1. Introduction

Prior to the launch of the *COMPTON Observatory* there were only four extragalactic sources which had been detected above 100 keV: Cen A, NGC 4151, MCG 8-11-11 and 3C 273 (Levine et al. 1984, Perotti et al. 1981b). Only one extragalactic source, the nearby quasar 3C 273, was detected above 50 MeV by COS-B (Swanenburg et al. 1978). AGN observed in the 1-50 keV energy band by HEAO were generally well fit with a "canonical" power-law spectrum with a spectral index of about 1.7 (Rothschild, 1983). More recent observations with the Ginga satellite (Pounds et al. 1990, Matsuoka et al. 1990) have shown Seyfert spectra which are more complex, including a hard shoulder above 10 keV and a fluorescent iron emission line in many Seyferts. These have been interpreted as evidence for a reflected component of an incident power law spectrum from a layer of cold material, presumably an accretion disk. Both thermal and non-thermal models have been proposed to explain the observed characteristics. Observations dating from the late 1960's had detected a diffuse gamma ray background at energies from 20 keV to several hundred MeV. The origin of this gamma ray background has been the focus of intense theoretical work, but remains a mystery. Although AGN, especially Seyfert galaxies, contribute to the diffuse gamma ray background, the fraction of this

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1995**	2. REPORT TYPE	3. DATES COVERED **00-00-1995 to 00-00-1995**

4. TITLE AND SUBTITLE **OSSE Observations of Active Galactic Nuclei**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,4555 Overlook Avenue, SW,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**12**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

background which is attributable to AGN is unknown. It was clear that the spectra of Seyfert galaxies had to break above several hundred keV in order not to overproduce the diffuse gamma ray background. However, emission consistent with the hard X-ray spectrum extending to above 1 MeV was reported for two Seyferts: NGC 4151 (Perotti et al. 1981a) and MCG 8-11-11 (Perotti et al. 1981b).

The *COMPTON Gamma Ray Observatory* was launched on 5 April 1991. It carries four instruments which undertake gamma ray observations from 20 keV to 20 GeV. The overall capabilities and characteristics of these instruments are described in a series of papers (Johnson et al. 1993, Thompson et al. 1993, Schoenfelder et al. 1993, Fishman et al. 1989). The first 18 months (Phase 1) of the mission were used to undertake a full sky survey with the COMPTEL and EGRET instruments. This was accomplished with a series of two and three week viewing periods (VP) during which the attitude of the observatory remained fixed.

OSSE operates in the 50 keV -10 MeV region, has a 3.8° x 11.4° field-of-view (non-imaging), and is used to study one object at a time. OSSE observed 35 active galaxies during the first two years of the mission. These sources comprise 15 Seyfert Type 1's, 9 Seyfert Type 2's, 4 BL Lacs, 5 QSOs, 1 radio galaxy, and 2 starburst galaxies. Table 1 lists the Seyfert galaxies which were OSSE targets. Table 2 provides a list of the QSOs and BL Lacs which were OSSE targets. The rather small number of QSOs reflects the Phase 1 observation plan prior to the EGRET discovery of the high energy AGN, as well as the large number of Seyferts which had been observed with hard spectra in previous hard X-ray surveys (Rothschild et al. 1983).

2. NGC 4151

An OSSE observation of NGC 4151 in 1991 (Maisack et al. 1993) measured a spectrum above ~50 keV which is similar to the SIGMA spectrum of 1990 but with a sensitivity far exceeding previous observations in this band. The spectrum for NGC 4151 observed in July 1991 is shown in Fig. 1. Contrary to previous measurements, the best power law fit to the OSSE spectrum, which gives a spectral index of 2.72 ± 0.07, is not an acceptable description of the spectrum. It is best modeled by a broken power law or by exponential shapes such as the thermal Comptonization model of Sunyaev & Titarchuk (1980) with temperatures of ~ 40 keV. This is in marked contrast to the hard spectrum, α ~1.3, observed by Perotti et al. (1981a) extending to several MeV. In a combined analysis of the 1991 OSSE data on NGC 4151 and the Ginga X-ray data from an observation one month earlier, Zdziarski, Lightman, and Zaciolek-Niedzwiecki (1993) confirm the essentially thermal nature of the spectrum. They proposed a modified non-thermal pair model in which the efficiency of the acceleration of relativistic electrons is ~20%. This inefficiency gives rise to a dominant thermal component with an annihilation feature from the non-thermal component. Although a pure non-thermal pair cascade model can be ruled out, a purely thermal explanation cannot be excluded.

Table 1: OSSE Observations of Seyfert AGN

Source[a]	Type	View Period	Start Date[b]	End Date	Flux[c] (50 – 150 keV)	Observ. Time[d]
3C 111	SY 1				2.81 ± 0.49	5.92
		4	91/180	91/193	3.10 ± 0.58	4.33
		29	92/136	92/156	2.06 ± 0.93	1.59
3C 120	SY 1				2.64 ± 0.38	10.01
		29	92/136	92/156	2.13 ± 0.96	1.48
		30	92/156	92/163	<2.22	1.44
		33	92/184	92/198	3.31 ± 0.77	2.93
		220	93/130	93/133	3.89 ± 1.50	0.57
		224	93/155	93/165	3.21 ± 0.60	3.59
3C 390.3	SY 1				2.68 ± 0.39	10.27
		12	91/291	91/304	4.09 ± 0.69	3.52
		29	92/136	92/156	2.82 ± 0.61	3.62
		209	93/041	93/053	<1.47	3.12
CEN A	SY 2				50.91 ± 0.43	8.12
		12	91/291	91/304	62.64 ± 0.55	5.70
		43	92/304	92/308	37.73 ± 1.10	1.14
		215	93/092	93/096	31.62 ± 1.39	0.54
		217	93/103	93/110	25.28 ± 1.20	0.74
ESO 141-55	SY 1				<1.80	2.21
		38	92/240	92/245	3.37 ± 1.23	1.20
		42	92/289	92/303	<2.62	1.00
IC 4329A	SY 1				7.00 ± 0.45	7.40
		41	92/283	92/289	4.19 ± 1.15	1.04
		44	92/309	92/322	5.92 ± 0.72	2.59
		207	93/013	93/033	GI	3.77
MCG +5-23-16	SY 2				<2.00	1.32
		36.5	92/226	92/233	<3.66	0.41
		39	92/246	92/261	<2.39	0.91
MCG +8-11-11	SY 1				3.68 ± 0.46	7.80
		31	92/163	92/177	4.02 ± 0.51	6.37
		222	93/145	93/151	2.20 ± 1.07	1.43
MCG -5-23-16	SY 2				4.03 ± 0.77	2.87
		35	92/220	92/224	4.60 ± 1.06	1.57
		36	92/224	92/225	<4.20	0.30
		38	92/241	92/245	4.87 ± 1.33	1.00

[a] First line per source is total of all observations
[b] Year/Day of Year
[c] $\times 10^{-3}\ \gamma\, cm^{-2} s^{-1} MeV^{-1}$
[d] $\times 10^{5}$ Det-sec

Table 1 (cont.): OSSE Observations of Seyfert AGN

Source[a]	Type	View Period	Start Date[b]	End Date	Flux[c] (50 – 150 keV)	Observ. Time[d]
MCG -6-30-15	SY 1				4.71 ± 0.61	3.65
		41	92/283	92/289	3.99 ± 1.15	1.05
		44	92/309	92/322	5.00 ± 0.72	2.60
MRK 279	SY 1	22	92/066	92/079	2.56 ± 0.66	3.88
MRK 335	SY 1				<1.80	2.15
		26	92/115	92/119	<3.15	0.70
		28	92/129	92/135	<2.38	1.27
		37	92/234	92/240	<5.63	0.18
MRK 509	SY 1				3.99 ± 0.95	1.69
		43	92/304	92/308	4.48 ± 1.36	0.74
		213	93/083	93/088	3.52 ± 1.33	0.94
MRK 841	SY 1	25	92/108	92/114	<5.27	0.21
NGC 1068	SY 2	21	92/052	92/065	<1.23	4.52
NGC 1275	SY 2	15	91/333	91/346	1.60 ± 0.57	4.01
NGC 2992	SY 2				<1.50	3.11
		30	92/157	92/163	<3.15	0.72
		33	92/185	92/198	<1.70	2.40
NGC 3783	SY 1	32	92/178	92/184	3.86 ± 1.38	0.94
NGC 4151	SY 1				27.93 ± 0.35	12.01
		4	91/180	91/193	28.58 ± 0.43	7.57
		24	92/094	92/100	24.28 ± 4.06	0.08
		24.5	92/101	92/107	14.87 ± 2.79	0.19
		218	93/111	93/123	25.95 ± 0.75	2.95
		222	93/145	93/151	30.54 ± 1.16	1.23
NGC 4388	SY 2	40	92/262	92/282	6.35 ± 0.58	5.22
NGC 4507	SY 1	208	93/034	93/040	GI	1.44
NGC 4593	SY 1.9				<1.96	1.41
		36.5	92/229	92/233	<3.66	0.40
		39	92/258	92/261	<3.52	0.40
		205	92/365	93/005	<3.07	0.60
NGC 5548	SY 1.2				3.78 ± 0.74	3.13
		7.5	91/227	91/234	3.34 ± 0.94	1.82
		12	91/291	91/304	4.66 ± 1.81	0.59
		13	91/305	91/311	4.37 ± 1.56	0.73
NGC 6814	SY 1	208	93/034	93/040	3.19 ± 0.83	2.39
NGC 7314	SY 1.9	27	92/120	92/128	<1.78	1.70
NGC 7582	SY 2				2.57 ± 0.67	3.58
		16	91/347	91/361	2.59 ± 0.81	2.56
		24	92/094	92/100	5.12 ± 1.62	0.54
		24.5	92/101	92/107	<4.84	0.24
		25	92/108	92/114	<4.75	0.25

Thermal models have long been used to describe the X-ray and gamma-ray emission of Cygnus X-1, a suspected black hole source, as well as X-ray emission from AGN. The onset of pair production in these models at temperatures of several hundred keV limits the maximum temperature of the emission region in thermal models to 1-2 MeV (Svensson 1984; Dermer 1989). A confirmation by OSSE of the intense gamma radiation extending to 10 MeV, as reported by the MISO experiment for NGC 4151 (Perotti et al. 1981a) and for MCG 8-11-11 (Perotti et al. 1981b) would provide a crucial test for thermal models of AGN.

The OSSE energy band is ideally suited for the study of the importance of non-thermal pair processes because it covers both the band where $\gamma\gamma$ pair creation is important and the 0.511 MeV pair annihilation feature appears. The combination of X-ray observations and OSSE observations is particularly useful in understanding the emission processes in AGN, as was demonstrated for NGC 4151. OSSE's observations of AGN in the first two years of the *COMPTON* mission were designed to measure the gamma ray spectra of AGN with known X-ray characteristics. Seyfert AGN from the HEAO-1 detections (Rothschild et al. 1983) as well as bright objects detected by EXOSAT and Ginga satellites were scheduled for OSSE observations. The objectives of the observations were to improve the spectroscopy into the MeV energy band with hopes of providing insight into emission mechanisms in AGN, the contribution of Seyferts to the cosmic diffuse background, and the importance of non-thermal processes in Seyferts which might explain the MeV emission reported from two Seyferts, NGC 4151 and MCG+8-11-11. These non-thermal processes would likely give rise to e^+e^- pairs which in turn could produce detectable pair annihilation features from these objects.

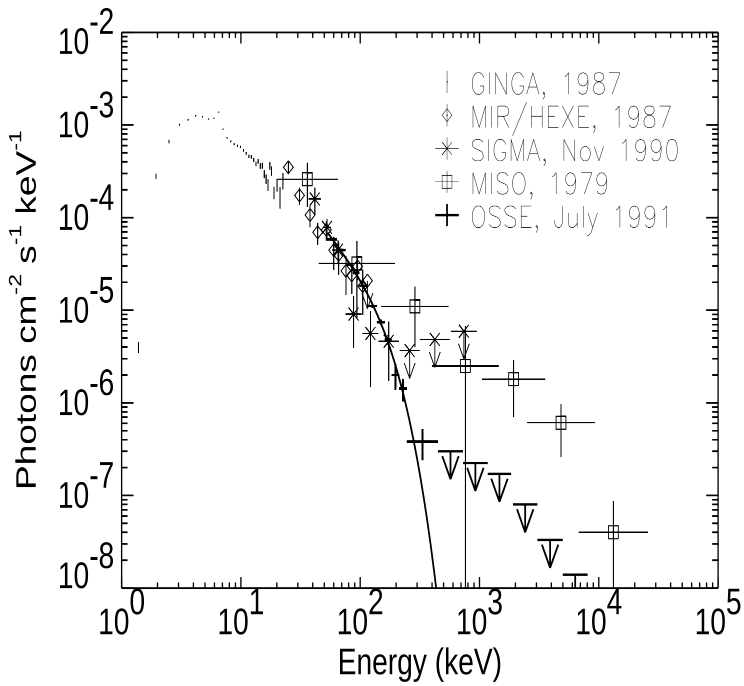

Figure 1. OSSE spectrum of NGC 4151 observed in July, 1991. The best fit Sunyaev-Titarchuk thermal comptonization model is shown (solid line) along with previous X-ray and gamma ray results.

3. Average Seyfert Spectrum

OSSE has observed only one Seyfert galaxy, NGC 4151, with sufficient statistical precision to address the thermal vs. non-thermal nature of the spectrum above 50 keV. The NGC 4151 spectrum is clearly thermal and, because of its softness and lack of a 0.511 MeV annihilation feature, places fairly restrictive constraint on non-thermal pair models (Maisack et al. 1993, Zdziarski et al. 1993). The softening or break in the spectrum of NGC 4151, if assumed to be typical of all AGN, removes the potential excess over the observed cosmic diffuse background and would bring the power law index of the composite AGN spectrum more in line with the diffuse index in the 100-400 keV band (Zdziarski et al. 1994).

The universality of the NGC 4151 spectrum is questioned on the basis of its transitions between type 1 and type 2 Seyfert characteristics (Ayani and Maehara 1991) and its lack of an apparent reflection component (Maisack and Yaqoob 1991) which is thought to be typical of Seyferts (Pounds et al. 1990). OSSE observations of the bright Seyfert 1, IC 4329A, when combined with Ginga X-ray data appear to be consistent with non-thermal models with a reflection component included (Fabian et al. 1993, Fabian et al. 1994, Madejski et al. 1994). In an effort to address the issue of the typical spectrum of Seyfert AGN, the OSSE data from all Seyfert observations with positive detections (here defined as >2 sigma) have been combined to produce an average Seyfert spectrum. The most intense observations (> 10 sigma detections) were excluded so that single sources would not significantly bias the result; this limit removed NGC 4151, NGC 4388 and IC 4329A from the average. The results are not significantly different when NGC 4388 and IC 4329A are included, however. The resultant sum included 26 observations of 14 Seyferts: 3C 111, 3C 120, 3C 390.3, ESO 141-55, MCG +8-11-11, MCG -5-23-16, MCG -6-30-15, Mrk 279, Mrk 509, NGC 1275, NGC 3783, NGC 5548, NGC 6814, and NGC 7582.

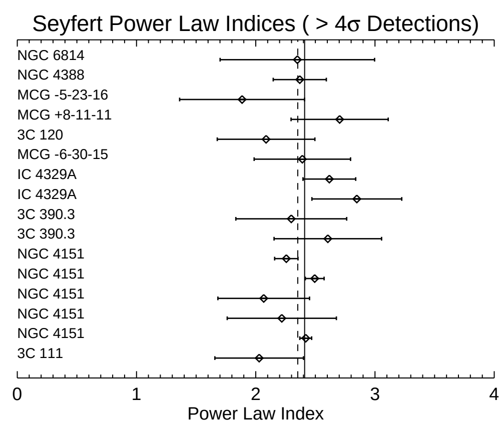

Figure 2. Power law spectral indices for those Seyfert galaxies detected by OSSE at a significance greater than 4 sigma.

The individual observations of these sources are well fit by simple power law or exponential models. The statistical precision of the measurements do not permit discrimination between the models. Figure 2 shows the best fit power law indices for the most significant detections (>4 sigma). NGC 4151 and IC 4329A are included in the figure for comparison. The average index for this set is 2.4 with a variance of 0.25 and is clearly softer than the typical power law index, $\alpha\sim 1.7$, in the X-ray band.

The weighted sum of the 26 OSSE observations of 15 Seyferts is shown in Figure 3. The spectrum is well described by a simple exponential with e-folding energy of ~46±5 keV (Johnson et al 1994). Sunyaev-Titarchuk (1980) thermal Comptonization models also provide acceptable fits with kT of 30 (+11, -6) keV and optical depth of 5.1 (+11, -2). The best fit power law model has an index, α, of 2.20 ±0.15. However the power law model is only a marginally acceptable description of the data with a χ^2 probability of 0.06. Figure 3 also shows, for comparison, the OSSE spectrum of NGC 4151 from the June, 1991, observation. The best fit thermal Comptonization model for NGC 4151 indicated kT of 35±4 keV and τ of 3.4± 0.6. (These values differ slightly from those in Maisack et al., 1993, because of an improved calibration of the OSSE instrument response.)

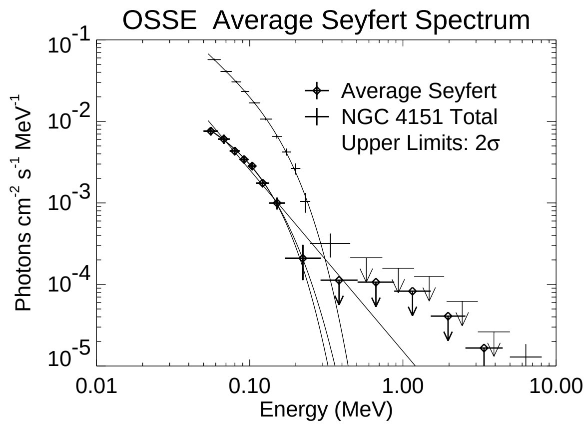

Figure 3. The average spectrum of weak Seyfert galaxies observed by OSSE. The spectrum of NGC 4151 is shown for comparison.

4. Short Term Variability

Most of the Seyfert galaxies observed by OSSE have been too weak to search for short term variability. However, for the two strongest AGN observed, Cen A and NGC 4151, the OSSE observations have enabled a search and observation of variability. For NGC 4151, Maisack et al. (1993) report that the source was detected at a significance of greater than 10σ per day in the 80-150 keV band. Over the 14 day observation, the source was observed to vary by ~25%, with the intensity changes of this level apparent on a time scale of about 2 days. This short term variability clearly requires that the low-energy gamma-ray emission is associated with the central power source in NGC 4151. Separating the observation into periods of low and high intensity did not indicate any change in the spectral shape.

Kinzer et al. (1994) report on preliminary results for the nearby radio galaxy Cen A. This is the strongest extragalactic source observed by OSSE. Although Cen A has been at historically low levels during the several OSSE observations reported over a three year period, both long term and short term variability are evident. In particular, short term variability with significant changes in intensity on time scales of 12-24 hours are observed. This places a limitation on the size of the emitting region in Cen A to be less that 10^{15} cm. This is the shortest low energy gamma ray variability that has been observed for an extragalactic object.

5. Blazars

As noted earlier, 3C 273 was the only extragalactic high-energy gamma ray source detected prior to the launch of GRO. However, the occurrence of a Type Ia supernova in NGC 4527, SN 1991t, resulted in an early change to the viewing program which enabled the Virgo region to be viewed in VP3 (June 1991). Surprisingly, 3C 273 was not observed by EGRET as an intense source, but the nearby OVV quasar 3C 279 was detected. 3C 279 was the first quasar for which superluminal motion was observed, and it had been recognized as a good candidate for gamma ray emission. Remarkably, EGRET observed significant variability in 3C 279's high-energy gamma-ray emission during the two week observation (Hartman et al. 1991). The source was observed to increase by a factor of 3 over a period of one week, and then decreased by a factor of 3 over a period of only two days. At a redshift of 0.538, the apparent γ-ray luminosity of the source is 1 x 10^{48} erg/s if isotropic emission is assumed. This luminosity is an order of magnitude larger that the luminosity in any other spectral band. The short term variability and the luminosity strongly indicate the high-energy gamma ray emission originates in relativistic jets with the radiation beamed toward the Earth. The short term variability probably results from the emission originating relatively close (a few light days) to the central compact object, and the intrinsic gamma ray luminosity is reduced from the apparent luminosity by the beaming factor.

The energy spectrum of 3C 279 is observed to be a power law in the EGRET energy range. During June 1991 when the strong flaring activity occurred, the photon spectral index was 1.9. Several months later, when the source was in a somewhat lower intensity state, the spectrum was slightly steeper, spectral index = 2.1. However, it should be noted that a weak, nearby source may have contributed to the EGRET spectrum for 3C 279 during the October observation (Hartman, this conference). Ginga observed this source several days prior to the EGRET observations in June, 1991, so contemporaneous X-ray observations are available.

During Phase 1 of the *COMPTON* mission, EGRET reported the detection of 16 extragalactic sources at greater that 5σ (Fichtel et al. 1993). All of the identified sources belong to the class of radio loud active galactic nuclei. Most are classified as flat spectrum quasars and four are BL Lacs. Six of the sources are associated with radio objects which exhibit superluminal characteristics. Identifications have been made with optical and/or radio objects in all but four cases. Short term variability has been observed for several of these sources where the detection is sufficiently significant to perform temporal studies. In all cases the spectra can be adequately described by a single power law, although there may be a suggestion for high energy steepening above 1 GeV in several of the sources. The range of redshifts extends to $z > 2$. This is also consistent with a subset from a population of objects in which the emission is beamed toward the observer.

Table 2: OSSE Observations of Blazars

Source[a]	Type	View Period	Start Date[b]	End Date	Flux[c] 50 – 150 keV	Observ. Time[d]
3C 273	QSO				9.60 ± 0.28	19.37
		3	91/167	91/179	14.61 ± 0.42	7.70
		8	91/235	91/248	4.81 ± 0.68	3.59
		11	91/277	91/290	3.49 ± 0.56	5.37
		36.5	92/226	92/228	14.16 ± 2.31	0.25
		39	92/252	92/256	16.78 ± 1.38	0.70
		204	92/358	92/364	7.81 ± 1.60	0.68
		205	92/365	93/005	4.22 ± 1.68	0.60
		206	93/006	93/012	7.68 ± 1.86	0.48
3C 279	QSO				3.84 ± 0.57	4.93
		10	91/263	91/276	6.73 ± 0.73	3.06
		39	92/246	92/251	<2.62	0.77
		204	92/358	92/364	<3.20	0.68
		206	93/006	93/012	<3.96	0.42
4C 04.77	BL LAC	37	92/234	92/240	<4.58	0.27
MRK 421	BL LAC				<1.01	5.08
		5	91/194	91/207	<1.78	1.81
		6	91/208	91/220	<1.45	2.24
		9.5	91/256	91/262	<2.31	1.02
PKS 0528+134	QSO				<1.95	1.84
		41	92/283	92/289	<3.41	0.62
		44	92/308	92/322	<2.38	1.22
PKS 0548-322	BL LAC	31	92/164	92/177	<4.46	0.37
PKS 2155-304	BL LAC	42	92/290	92/303	4.70 ± 1.15	1.30
QSO 0736+016	QSO	3	91/168	91/179	<1.55	2.46
QSO 0834-201	QSO				<2.21	1.45
		41	92/283	92/289	<4.60	0.33
		44	92/309	92/322	<2.51	1.11

[a] First line per source is total of all observations
[b] Year/Day of Year
[c] $\times 10^{-3}\ \gamma\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{MeV}^{-1}$
[d] $\times 10^{5}$ Det - sec

One of the objectives of the *Compton Observatory* is to obtain broad band γ-ray coverage of a variety of sources. OSSE has observed several of the blazars which have been detected by EGRET and these are listed in Table 2. McNaron-Brown et al. (1994) have presented preliminary spectra for several AGN over the gamma ray band from 0.1 MeV to 10 GeV. These are shown in Figure 4 and include spectra for 3C 273, 3C 279, PKS 0528-134 and Mrk 421, which have been detected by EGRET at high energies and for which OSSE and/or COMPTEL observations have been made or for which significant low-energy upper limits exist.

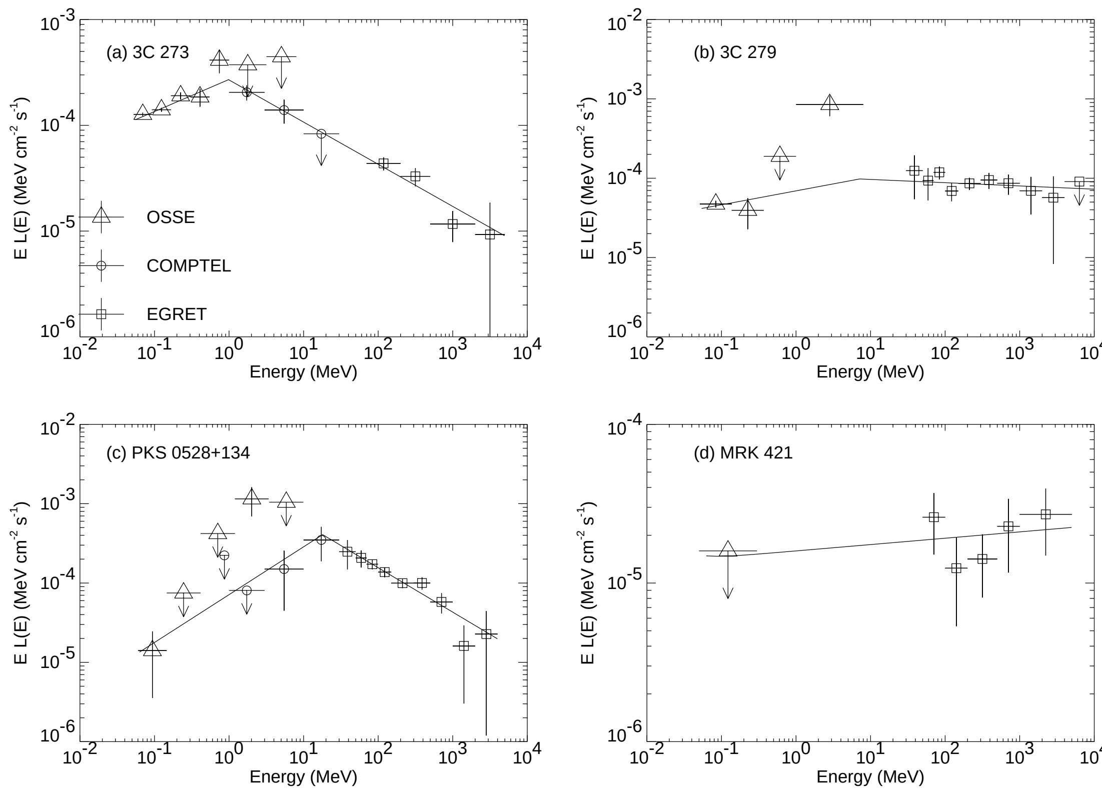

Figure 4: 0.1 MeV - 10 GeV spectra for four AGN: (a) 3C 273, (b) 3C 279, (c) PKS 0528+134, and (d) Mrk 421.

The GRO spectrum of 3C 273 in June, 1991 is shown in Figure 4a. During this observation, 3C 273 was relatively weak in high-energy gamma rays compared to the COS-B observation, and was also weak in low-energy gamma rays compared to historical data. The spectrum is characterized by a broken power law with a break near 2 MeV, and a change in spectral index of 0.66.

The spectrum for 3C 279 is shown in Figure 4b. The EGRET data were taken in VP11 when OSSE was not observing the source. These are compared with OSSE data from VP10. It should also be noted that the high-energy gamma ray emission during VP3 showed clear variability, raising caution about over-interpreting these data, which are not simultaneous. Nevertheless, the EGRET data during VP3 and VP11 showed little change in intensity at the lower energy of the EGRET band (100 MeV). A broken power law fit to the VP10/VP11 data suggests only a small change in index in the GRO energy range, and the combined data are consistent with a single power law of index about 2.0

The spectrum for PKS 0528+134 is shown in Fig. 4c. This quasar, at a redshift of 2.08, has been detected by EGRET and COMPTEL, but OSSE only has upper limits for a non-

contemporaneous observation. This source exhibits one of the softer spectra observed by EGRET (α = 2.6). COMPTEL observes a weak signal, which requires a spectral break near 20 MeV. A spectral break of $\delta\alpha \geq 1.0$ is also required by OSSE limits in the 0.1-1.0 MeV region.

The spectrum of the nearby BL Lac, Mrk 421, is shown in Fig 4d. Mrk 421 is the only extragalactic source observed at TeV energies by ground-based gamma ray detectors (Punch et al. 1992). EGRET has obtained a spectrum with a power law index of 2.0 which agrees with the TeV data when extrapolated to higher energies. The OSSE upper limits at 100 keV are not constraining on the spectrum, so it is possible that this α= 2.0 power law extends unbroken from 0.1 MeV to 1 TeV.

Even though the spectra of AGN observed by EGRET can be fit with power laws, broad band GRO data indicate that spectral breaks occur at energies ranging from less that 0.1 MeV to above 1 GeV. In the case of PKS 0528+134 the magnitude of the break is $\delta\alpha \geq$ 1.0 and occurs near 20 MeV, while in 3C273 the spectral break, $\delta\alpha$ = 0.66, occurs at lower energy, ~2 MeV. The energy and magnitude of the spectral break should provide information about the emission mechanism and/or geometry of the relativistic beams in these sources.

6. Multi-Wavelength Campaigns

It is clear that significant progress in the understanding of AGN are derived from simultaneous observations across the electromagnetic spectrum. Several future COMPTON observations will be devoted to participation in such multiwavelength campaigns. In the Phase 3 observing program there has been a multi-wavelength campaign to observe NGC 4151 in December, 1993. There was also an eight week campaign which obtained coordinated observations with the OSSE, EGRET and COMPTEL instruments of the Virgo region. Coordinated observations at other wavelengths were also organized in connection with the Virgo survey.

7. Summary

OSSE has made several important contributions to the understanding of AGN during the first two years of the mission. These include:

1. Measurements of the low-energy gamma ray spectra of Seyfert galaxies. These spectra, typified by NGC 4151, are much steeper above 50 keV than below 50 keV. No evidence for positron annihilation features or MeV excesses, reported previously, have been observed. This seems to suggest a thermal origin for the radiation, similar to that observed in several galactic black hole candidates. These observations also appear to resolve the problems of limiting the contribution of Seyfert galaxies to the diffuse gamma ray background in the several hundred keV region.

2. Low-energy observations of several of the new class of high-energy gamma ray emitting AGN associated with radio loud, core-dominated sources. The Combined OSSE/COMPTEL/EGRET broadband spectra indicate a wide range of spectral characteristics for these sources, with spectral breaks of 0-1 or more in the MeV region.

3. Evidence for ~day time scale variability for NGC 4151 and Cen A which indicates that the low-energy gamma ray emission is associated with the nuclei of these AGN.

Acknowledgments

This work was supported by NASA DPR S-10987c.

References

Ayani, K. and Maehara, M.. 1991 Publl. Astr. Soc. Japan, **43**, L1
Dermer, C. D. 1989, in Proc. 14th Texas Symposium on Relativistic Astrophysics, ed. E. Fenyves (New York Academy of Sciences, New York), p. 513
Dermer, C. D. 1993, AIP Conference Proceedings, **280**, 541
Fabian, A., et al., 1993, ApJL, **416**,L57
Fabian, A., et al., 1994, ApJL, **421**, L95
Fichtel, C.E., et al., 1993, AIP Conference Proceedings, **280**,461
Fishman,G.J. et al. 1989, Proceedings of the GRO Science Workshop, 2-39.
Hartman, R.C. et al., 1992 Ap. J., **385**, L1
Johnson, W.N. et al., 1994, to be published in Proc. Second *COMPTON* Symposium.
Johnson, W.N., et al., 1993, Ap. J. Supp. **86**, 693.
Kinzer, R.L. et al. 1994, to be published in Proc. Second *COMPTON* Symposium.
Levine, A.M., et al., 1984, Ap. J. Supp., **54**, 581.
Madejski, G.M., et al., 1994, accepted for publ. in Ap. J.
Maisack, M. and Yaqoob, T. 1991, Astron. & Astrophys., **249**,25
Maisack, M., et al., 1993 Ap. J. **407**, L61.
Matsuoka, M. Piro, L., Yamauchi, M., Murakami, T., 1990. Ap.J., **361**, 440
McNaron-Brown, K., et al., 1994, to be published in Proc. Second *COMPTON* Symposium.
Perotti, F, et al., 1981a, Ap. J. **247**, L63.
Perotti, F., et al., 1981b, Nature, **292**, 133.
Pounds, K. A., et al., 1990, Nature **344**,132
Punch, M., et al., 1992, Nature **358**,477.
Rothschild, R.E., et al., 1983. Ap. J. **269**, 423.
Sunyaev, R. A., and Titarchuk, L. G., 1980, Astron. & Astrophys., **86**,121
Svensson, R. 1984, MNSAS, **209**, 175
Swanenburg, B.N., et al., 1978, Nature **275**, 298.
Schoenfelder, V., et al., 1993, Ap. J. Supp. **86**, 657.
Thompson, D. J., et al., 1993, Ap. J. Supp. **86**, 629.
Zdziarski, A.A., Lightman, A.P., and Maciolek-Niedzwiecki, A.,1993, ApJL, **414**, L93
Zdziarski, A.A., Zycki, P.T., and Krolik, J.H., 1994 Ap. J. **414**, L81